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# Ergonomics and Skidder Operations in Northern Ontario: A Preliminary Investigation

R.D.G. Webb and R.A. Hope

Information Report DPC-X-15

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## ENVIRONMENT CANADA

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# Ergonomics and Skidder Operations in Northern Ontario: A Preliminary Investigation

by

R. D. G. Webb[1] and P. A. Hope[1]

Information Report DPC-X-15

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[1]Ergonomics Unit, School of Human Biology,
University of Guelph

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## ABSTRACT

Twenty-five skidder operators were observed at work in Northern Ontario and twenty-three operators were interviewed. Twenty-one skidders were assessed for noise, whole-body vibration and/or exit and entry and internal cab dimensions. Ergonomic considerations recommended for further consideration include whole-body vibration levels, mounting and dismounting frequency, thermal conditions, and feller-skidder operator communication. Several specific modifications to cab entrance and internal characteristics are discussed.



## RÉSUMÉ

Le présent document rend compte de l'observation de 25 débusqueurs au travail dans le nord de l'Ontario et des entrevues avec 23 d'entre eux. Vingt-et-une débusqueuses ont été évaluées quant aux bruits, aux vibrations globales du corps et (ou) à la sortie ou l'entrée de la cabine ainsi que ses dimensions internes. Les études ergonomiques recommandent l'analyse des taux de vibrations globales du corps, de la fréquence des montées et des descentes, des conditions thermiques, et des communications entre le bûcheron et le débusqueur. Plusieurs modifications précises de l'entrée de la cabine et de ses caractéristiques internes sont traitées.

## ACKNOWLEDGEMENTS

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# EXECUTIVE SUMMARY

## Objectives

1. Provide a preliminary survey of ergonomic factors in skidder operations.
2. Identify ergonomic factors worth further investigation.
3. Comment upon the conditions observed with respect to well-being and performance.

## Outline

Skidder operations in 17 locations were observed. The following factors were assessed:

1. Work cycle characteristics
2. Environmental characteristics - Thermal, Noise, Whole-body vibration
3. Internal cab characteristics including seating
4. Exit and entrance characteristics.

Twenty-three operators from the locations observed were interviewed. The interview schedule consisted of 84 questions covering the following topics:

1. Biographical details
2. Description of work cycle
3. Learning the job
4. Work organization
5. Accidents and hazards
6. Muscular fatigue
7. Mounting/dismounting
8. Cab dimensions
9. Seating
10. Instruments/controls
11. Environment
12. Modifications.

## Conclusions

1. Although there were constraints on sample selection and sample size, the characteristics of the sample observed seem to be generally indicative of skidder operations.
2. Frequent and intensive sudden impacts caused high levels of whole-body vibration. Operators were frequently thrown against the inside of the cab. The potential consequences of spinal and other internal disorders resulting from the vibration levels observed are cause for concern.
3. Noise levels were mostly above recommended levels. Hearing protection was generally disliked, and perceived to interfere with essential auditory information.
4. Thermal conditions interacted with activity and clothing. Probably would produce accelerated body cooling in winter during less active phases of the work cycle.

5. Frequency of mounting and dismounting was high and interacted with mounting/dismounting habits, seat belt use, and the potential for cab climate control, slips and falls. Mounting and dismounting were observed by operators as major causes of fatigue.
6. Lack of communication between feller and skidder was potentially hazardous.
7. Deficiencies in internal cab characteristics included a lack of
   - head room
   - storage space
   - grab bars
   - protective cushioning
   - seat adjustability
   - climate control.
8. Deficiencies in exit/entrance characteristics included
   - grab rail dimensions
   - step dimensions
   - exit space.
9. Most operators had received little or no formal training.

**Recommendations**

1. Primary consideration should be given to reducing exposure to whole-body vibration and frequency of mounting/dismounting.
2. Further investigation is necessary to confirm and extend these results particularly whole-body vibration. More information is needed concerning
   - Whole-body vibration
     vehicle speed, driving habits, performance and vibration
     impact frequency and intensity
     long-term effects on operators
   - Mounting/dismounting frequency and habits in relation to work-cycle demands
   - Feller-skidder operator communication
   - Thermal conditions.
3. Investigate the potential for short-term improvements in
   - Internal and external grab handles
   - Step and entrance characteristics
   - Seat characteristics
   - Internal head room and protective padding
   - Thermal and visibility characteristics of clothing.

## DEFINITIONS

The metric system of units has been used throughout this report. The following glossary briefly describes some of the units and abbreviations used.

Leq: a unit referring to the equivalent steady state level of a continuously fluctuating variable.

sd: standard deviation. A measure of within sample variability.

se: standard error. An estimate of the precision of the mean value of the sample as a predictor of the mean value in the general population.

dB: decibel. A logarithmic measure used for noise and vibration.

dBA: a weighted logarithmic measure used for noise when evaluating its impact on human beings.

x-axis: the front-back axis of the body when referring to whole-body vibration.

y-axis: the left-right axis of the body when referring to whole-body vibration.

z-axis: the vertical axis of the body when referring to whole-body vibration.

SRP: Seat Reference Point. A reference point at the base and back of the seat where the vertical plane of the backrest intersects with the horizontal plane of the seat pan.

n: the number of observations summarized by the statistic shown.

$\bar{x}$: the symbol for the mean value.

## INTRODUCTION

It is often said that limits to improved or even efficient systems operations are no longer so much mechanical as human. For example, the high cost of productivity for Canadian logging by comparison with competing areas (Industry, Trade and Commerce 1978) may be due to adverse Canadian conditions. However, this fact underlines the need to optimize human factors in man-machine systems. Commenting upon this, Cottell et al. (1980) cite a range of mechanical and human factors likely to contribute to reduced machine availability and poor productivity. Such factors will be aggravated by costly accidents. Not only must direct compensation costs be considered, already high for the forestry industry, but also indirect costs. These are estimated by some to be as high as six times the direct costs and include the loss of experienced workers, machine idle-time, the cost of selecting and training replacements as well as legal and other costs.

Most occupational tasks can be considered as man-machine-environment systems. This approach allows man-machine and man-environment interface problems to be identified and minimized with greater ease. This in turn allows the human component to operate with greater efficiency in relation to systems objectives. In both the short and the long term, this approach will result in a more cost-effective system: performance will be optimized, learning time minimized, absenteeism and labor turnover reduced, and accidents avoided.

Canadian logging encompasses a variety of harvesting systems. One of the least mechanized but most common is the cut and skid team. This team typically consists of one feller and one skidder operator. In this study, the occupational stresses associated with operating a skidder to haul cut logs from the bush were examined in terms of their potential impact on the performance and well-being of the operator, and hence the efficiency of the skidder system as a whole.

In a typical work cycle the skidder operator drives the skidder from the landing to the cutting area. In the cutting area, the operator positions the skidder appropriately, dismounts and hauls out the mainline and chokers to the logs. As soon as the chokers have been attached, the operator returns to the skidder, remounts and winches in the logs. This latter procedure may be repeated several times until a full load of logs has been winched in. The operator then drives the skidder back to the landing where the load of logs is dropped, piled, and butted. This work cycle is then repeated, each cycle taking about 20 minutes, and 20-25 cycles are completed on most working days.

Little is known about the demands placed upon the operator within this work cycle, or the consequences of those demands for the individual or for the system. Therefore this study was undertaken to investigate the job of the skidder operator and make a preliminary assessment of the ergonomic factors involved under one set of Canadian conditions. The scope of the study was restricted to the typical work cycle described above. Maintenance tasks were excluded from the study.

An outline of a simple man-machine-environment system is shown in Figure 1.

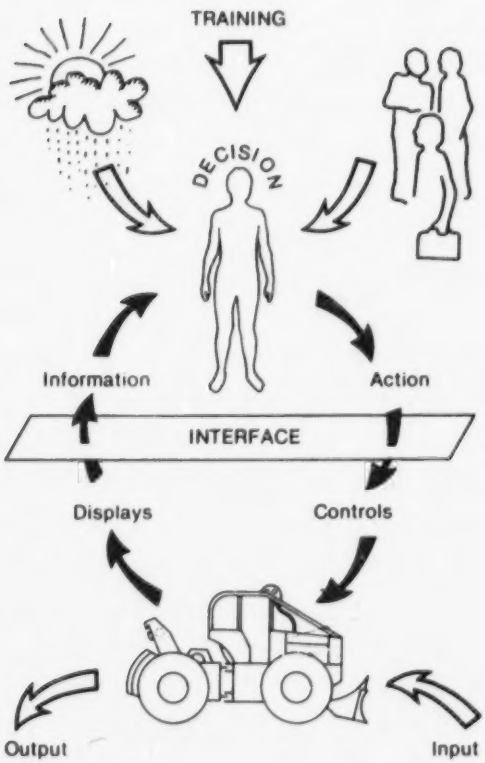


**FIGURE 1: A man-machine-environment system**

# METHOD

## Outline

During July and August 1982, skidder operations in two geographical areas were examined: Thunder Bay and New Liskeard.

Twenty-five operators (mean age 34.4 years) were observed at work and their work cycle times recorded. Twenty-three of these operators were interviewed. All operators were male. Five operators owned their machines. The remainder drove company-owned machines. All the owner operators worked in 2-man crews. Nine of the company operators worked in 2-man crews and eleven in 3-man crews.

Ten different models of machine from five different manufacturers were compared against a checklist for internal cab dimensions and layout, and exit and entry characteristics. The checklist was derived from Aminoff et al. 1980, Purcell 1980, Bottoms et al. 1979, and Couch and Fraser 1981.

Noise levels were recorded on 17 different machines from 5 different manufacturers. Whole-body vibration levels were recorded on 21 machines from 5 different manufacturers.

## Apparatus

Noise levels were recorded using a Bruel and Kjaer noise dosimeter type 4425 and a Bruel and Kjaer sound level meter type 2225.

Vibration levels were recorded using a Bruel and Kjaer Human Response Vibration meter type 2512 and a tri-axial seat accelerometer type 4322.

## Interviews

Interviews were conducted according to a predetermined question schedule. This schedule was based upon a review of other studies (Pasmooij and van der Grinten 1981; Aminoff et al. 1980; and Rehschuh and Tzschockel 1979) and discussions with some of the authors whose assistance is gratefully acknowledged. Eighty-four different questions were asked in the following categories:

1. Biographical details
2. Description of work cycle
3. Learning the job
4. Work organization
5. Accidents
6. Muscular fatigue
7. Mounting/dismounting
8. Cab dimensions
9. Seating
10. Instruments/controls
11. Environment
12. Modifications.

Interview questions were guided by the question schedule, but the interviews were kept as informal as possible. Interviews lasted approximately 75 minutes.

**Procedures**

For each work crew observed, contact was first made through the supervisor. The purpose of the study was explained and the work crew was observed for a few work-cycles. During this time a subjective estimate of the terrain was made and the machine model and year of manufacture noted.

After this, the seat accelerometer was put in place and the carrying case for its associated instrumentation was securely fixed to the skidder. See Figure 2 for a typical mounting. The use of the noise dosimeter was explained and the dosimeter worn by the operator.

**FIGURE 2: Instrument mounting**

Once the installation procedure was complete, the operator returned to work and worked in his usual manner. Before each work-cycle the instrumentation was reset and restarted. After each cycle the operator dismounted, the instrumentation was stopped, and the levels for that cycle recorded. During each cycle, subcomponents of the work-cycle were timed and notes were taken about the activity patterns observed. The frequency and the manner of mounting and dismounting were also recorded. In most instances at least three complete work-cycles were recorded in this manner.

Once the work-cycle recording was complete, the instruments were retrieved and the operator asked for his comments. A time for an interview was arranged. Every attempt was made to arrange this interview when privacy would be achieved. In most cases the interview took place in the evenings back at the logging camp. On some occasions the interview took place during the lunch break. On three occasions an interpreter was needed.

At a suitable break in the working day, sound levels were recorded with the machine stationary and the engine idling and running at full throttle. For this measurement, the microphone of the meter was held at approximately the operator's head level but with the operator absent from the cab.

# RESULTS

## Introduction

This section summarizes the main results. Further details are presented in the Appendices which are available separately on request.

## Work-cycle times

The average cycle time observed was 17.3 minutes (see Method). During the cycle the operator spent 10.6 minutes inside the skidder driving or winching in, and 6.7 minutes outside the vehicle attaching or detaching chokers. During the typical cycle an operator mounted and dismounted 10 times.

## Noise-levels

Noise levels are shown in Table 1. These figures represent the average of 17 machines (9 different models) ranging in age from 2 to 16 years. The 7-hour noise dose and operating noise levels represent data from 57 work-cycles.

Table 1. Noise levels

| Measurement | Mean | se* |
|---|---|---|
| 7-hour noise dose | 191.0% | 18.8 |
| Idling noise level | 82.8 dBA (Leq) | 0.8 |
| Operating noise level | 93.6 dBA (Leq) | 0.8 |
| Full throttle noise level | 99.2 dBA (Leq) | 1.0 |

*se - standard error

## Whole-body vibration levels

Whole-body vibration levels for the vertical z-axis are shown in Table 2. These figures represent data from 21 machines (9 different models) and 60 work-cycles.

Table 2. Whole-body vibration levels (z-axis)

| Measurement | Mean | se |
|---|---|---|
| z axis acceleration | 117.8 dB (Leq) | 0.3 |
| z axis peak | 148.7 dB | 2.0 |
| Dose/cycle* | 46.4 % | 6.2 |
| Mean cycle time | 19.0 minutes | 1.0 |

*Fatigue decreased proficiency limits - ISO 2631 - 1978E

Table 3 shows vibration levels in the x and y axes (pitch and roll) for 7 work-cycles and 4 machines.

Table 3. x and y axis Whole-body vibration levels

| Measurement | Mean | se |
|---|---|---|
| x axis acceleration | 119.2 dB (Leq) | 0.6 |
| x axis peak | 146.4 dB | 3.8 |
| Dose/cycle* | 23.9 % | 3.6 |
| Mean cycle time | 11.8 minutes | 0.8 |
| y axis acceleration | 116.9 dB (Leq) | 0.6 |
| y axis peak | 141.4 dB | 1.4 |
| Dose/cycle* | 11.4 % | 2.6 |
| Mean cycle time | 13.4 minutes | 0.9 |

*Fatigue decreased proficiency limits - ISO 2631 - 1978E

**Internal cab dimensions**

Table 4 shows the number of machines meeting the recommendations of standard checklists for internal cab dimensions (Aminoff et al. 1980; Purcell 1980; Pasmooij and van der Grinten 1981; Zerbe 1979).

Table 4. Cab dimensions

| Measurement | Recommendation | Acceptable |
|---|---|---|
| Cab width | 90 cm min. | 10/10 |
| Cab height | 160 cm min. | 1/10 |
| Cab depth | 130 cm min. | 3/10 |
| SRP* - Right wall | 45 cm min. | 9/10 |
| SRP* - Left wall | 45 cm min. | 10/10 |
| SRP* - Front | 65 cm min. | 10/10 |
| SRP* - Floor | 40 - 50 cm | 7/10 |

*SRP - Seat Reference Point

**Seat characteristics**

Table 5 shows the number of machines meeting the checklist recommendations for seat characteristics.

Table 5. Seat characteristics

| Measurement | Recommendation | Acceptable |
|---|---|---|
| Backrest | | |
| Width | 40-50 cm | 4/10 |
| Height | 40-50 cm | 1/10 |
| Angle | 95-110° | 0/10 |
| Adjustability | required | 0/10 |
| Cushion | | |
| Width | 44 cm min. | 10/10 |
| Thickness | 4-10 cm | 7/10 |
| Adjustability | required | 0/10 |
| Movement | | |
| Vertical | 10 cm | 0/10 |
| Forward/backward | 6 cm | 3/10 |
| Armrest | required | 0/10 |

**Cab entrance**

Table 6 shows the number of machines meeting the checklist requirements for cab entrance.

Table 6. Entrance dimensions

| Measurement | Recommendation | Acceptable |
|---|---|---|
| Door | | |
| Height | 160 cm min. | 1/10 |
| Width | 62 cm min. | 0/10 |
| Step height | | |
| Step 1 | 40 cm max. | 0/10 |
| Step 1 - 2 | 20-30 cm | 2/10 |
| Step 2 - 3 | 20-30 cm | 2/2 |
| Step width | 30 cm min. | 5/10 |
| Step depth | 10 cm min. | 5/10 |
| Grab rails (Base-ground distance) | | |
| Left rail | 160 cm max. | 0/10 |
| Right rail | 160 cm max. | 0/10 |

**Controls**

Table 7 shows whether the controls identified fell within the comfort zone recommended by the checklists.

Table 7 Control positions

| Control Function | Acceptable |
|---|---|
| Steering | 7/10 |
| Blade | 2/10 |
| Transmission | 5/10 |
| Winch | 0/10 |

**Instrumentation**

Table 8 shows the acceptability of instrument design in terms of checklist recommendations.

Table 8 Instrument design

| Instrument Function | Acceptable |
|---|---|
| Central location | |
| Oil pressure | 1/9 |
| Water temperature | 6/9 |
| Color coded | 5/9 |
| Unobstructed view | 3/9 |
| Symmetrical layout | 3/9 |

**Interviews**

Full details of questions and responses are given in the Appendices available separately from this report. A summary of the responses to the questions is given below.

Work-cycle

Operators reported two difficult aspects of the job. One concerned the physical difficulties of hauling out the mainline, mounting and dismounting, and the sustained

jolting while driving. The other concerned difficulties with tasks requiring skills and experience such as piling the logs, attaching chokers correctly, driving over rough ground, and winching in.

Learning the job

On average, operators reported that it took 6 - 8 weeks to learn to operate the skidder effectively. However, some operators took as long as 6-7 months. Most of the operators interviewed had received no formal training and were largely self-taught, with a little help from supervisors or salesmen. Two operators had been on 8-month college courses and one had been through a 2-day company training course. Those operators who had had no training reported that it took them longer to feel they were working effectively.

Nearly all operators interviewed (91 percent) had had experience in the bush as fellers before becoming skidder operators. Most (70 percent) had also had experience with other heavy vehicles. The most important skills were considered to be, in order, awareness of feller, awareness of terrain and obstacles, awareness of the machine's power and stability. The most difficult tasks to learn were reported as, in order, piling, control manipulation (several reported problems when transferring to a machine with a different control layout), backing into position, estimating the machine's pulling power and stability, and choosing the best sequence of attaching the chokers to the logs.

Work organization

Teamwork was cited as an important component of the job. The need for frequent discussion and familiarity with each other's preferred work pattern was often mentioned.

Communication between feller and operator was often difficult and usually took place with hand-signals. A common auditory signal was to switch off one's machine to indicate a need to talk. Most operators (77 percent) reported that an important signal from their feller had been missed at one time or another. Operators were concerned when they could not locate the whereabouts of their feller and the most commonly used cue was the noise of the chain-saw. In thick undergrowth or reduced visibility, operators frequently removed their hearing protection or switched off their skidder engines in order to locate their feller.

Working hours differed between owner and company operators. Owner operators worked longer hours in the summer (9-11 hours/day) and took a longer lunch break but did

not take a break in the afternoon. A marked preference for working in the Fall or Winter rather than the Summer or Spring was shown by all operators.

Accidents

The most common hazard was from objects flying into the cab. Other perceived hazards, accidents, or near accidents reported included the skidder tipping over, slips and falls when dismounting, slipping or jamming hands or feet when attaching chokers or hauling the mainline, and the jolting received when driving on rough terrain.

Muscular fatigue

Reports of soreness or pain in the back, neck, arms, and shoulders were common and associated by the operators with the jarring received during driving. Reports of fatigue in the legs were also common and associated with the frequent mounting and dismounting. Sometimes dismounting jarred operators' backs.

Mounting and dismounting

Mounting and dismounting caused many slips and falls. Most operators jumped down while facing away from the cab. The usual reasons given for this were that lack of space made turning before exiting awkward, and facing towards the cab prevented seeing where to put one's feet. Facing away from the cab when dismounting was seen as faster, required less effort and was safer.

Cab dimensions

Larger operators felt the cab was too small and several operators would have liked more storage space within the cab. Many operators commented on the lack of head room, and several reported heavy blows to the head as they were thrown around inside the cab while driving. Short operators reported some difficulty in reaching foot or hand controls. When foot controls were too far away, operators had to sit forward and lost the support of the seat backrest.

Many operators commented upon the restricted field of view especially towards the rear. The awkward posture required to see behind the machine induced considerable fatigue. If, as frequently happened, a jolt was received while the spine was twisted when looking to the rear, this was especially unpleasant.

Seating

Most operators (78 percent) felt the shock absorption characteristics of their seats were inadequate. Most seats had no suspension at all. Lighter operators bounced around

on suspension seats, and on big bumps, the suspension seats would bottom out. This was particularly disliked. In winter seats usually froze and added considerably to the jarring received. The sides of some backrests obstructed body movement when twisting to look to the side or rear. No operator used the seat belt provided; all cited the frequent mounting and dismounting as the reason.

Instruments and controls

Many operators found the hand controls awkward to use and commented on the lack of standardization between machines. Awkward wrist and forearm movements were often mentioned. Some operators had modified control levers to move confusing controls further apart or to make control movement easier.

Environmental conditions

The thermal environment was seldom seen as adequate. In the summer, heat from the machine added to the thermal stress. Fans had been fitted in some machines but as often as not the fans blew dust into the operator's face. In the winter, if the operator wore enough clothes to keep warm while driving, then sweating occurred while he was attaching chokers. Sweating reduced the insulation value of the operator's clothing and resulted in accelerated cooling when he was sitting in the cab during driving. The cold was accentuated by the steel floors in the cab and the lack of protection from the wind. A major complaint was the seat. The seat was not only cold, but often frozen hard.

Most operators disliked wearing hearing protection because it interfered with the location of the noise from their feller's chain-saw and because of discomfort from sweating in the summer. Most operators did not think hearing loss was a problem, claiming they had become used to the noise.

Vibration during driving was the most disliked aspect of the environmental conditions experienced. It was perceived by operators as the cause of back pain, of frequent knocks to them when they were thrown around inside the cab, and of fatigue to their arms because they had to hang on inside the cab. The lack of adequate internal grab handles and bracing points for the upper body was commented upon. Also reported was the improper operation of the controls as the operator was thrown around.

Modifications

Modifications suggested or already installed included thermal cushions for seats, internal grab handles, external grab handles, extra steps, fans, extra storage space, and internal padding on the cab ceiling and sides.

## DISCUSSION

The purpose of this study was to serve as a preliminary investigation. The validity of the comments made below depends not only upon the accuracy of the measurements made, but also upon the degree to which the conditions observed are representative of skidder operations as a whole.

The sample was not large and the basis of selection open to bias, but apparently there is no significant reason not to believe that these results are not generally indicative of conditions elsewhere. Nevertheless any conclusions based upon the data reported here should be regarded as tentative and subject to confirmation by studies able to concentrate in more detail on selected aspects. The usefulness of this study is in guiding that selection.

### Mounting and dismounting

A prominent feature of the work-cycle was the frequent mounting and dismounting. Ten mounts and dismounts for each cycle implies that operators mount and dismount some 200 times daily. Most operators found this a significant source of stress. Two factors may be of concern here: fatigue and the probability of slipping.

The overall level of fatigue will increase with frequency. Fatigue in the legs will increase both with the overall height climbed and the height of individual steps. Awkwardly placed grab bars will place extra stress on arms as the body is hauled into position. This effect will be accentuated if steps are not staggered inwards because the legs will be unable to provide an efficient upward force and the arms must be used to keep the body from falling outwards. Shorter operators will be more adversely affected by large step heights and out-of-reach grab handles. Generally, older or heavier operators would find mounting and dismounting more demanding. Most operators did not or could not follow the three-point contact principle (Couch and Fraser 1981).

Individual step dimensions and surface structure will affect the foot-to-step contact area and friction, which in turn, will affect the level of stress on ankle joints and the probability of slipping. The amount by which the body's centre of gravity is off balance when any slip occurs will determine the consequences of that slip for the individual.

A high frequency of mounting/dismounting will not only be associated with a higher probability of slipping but will also partly determine operator attitudes to time-consuming safety procedures such as dismounting by facing the cab. In this instance the procedure was also perceived as intrinsically unsafe because it interfered with the selection of a safe footing on the ground. This may or may not be so, but it deserves systematic

investigation because slips and falls are major causes of accidents. Operators also claimed that cab entrance dimensions made turning prior to dismounting difficult. This seems more likely to be true for larger operators.

If any way could be found to reduce the requirement for frequent mounting and dismounting then several benefits might follow. Furthermore, the majority of machines measured failed to meet criteria recommended in the literature for door, step, and grab rail dimensions.

**Whole-body Vibration**

The measured levels of whole-body vibration in each axis were extremely high: well beyond the limits recommended by ISO 2631-1978E. Immediate consequences for the operators were jarring of the spine, being thrown against the inside of the cab, and improper operation of controls when jolts occurred. Even in the absence of jolting, it is likely that performance is significantly impaired in terms of control operation and visual perception. The most likely manner in which operators adjust to vibration is by reducing driving speed. Operators already experiencing low back pain would likely reduce speed more than others. Probably, inexperienced or younger operators might do more damage to themselves and to their machines because of their emphasis on speed.

Longer term consequences of the vibration levels observed are likely to include chronic low back pain and internal disorders. Such disorders have been associated with agricultural tractor driving, which probably imposes lower levels of whole-body vibration (Rosegger and Rosegger 1960; Bottoms and Barber 1978; Braunbeck and Wilkinson 1981). A noteworthy aspect of the Rosegger study was that spinal deformation could be detected clinically long before operators made any subjective complaints and that such complaints took several years to come to light.

A major aspect of the vibration observed in this study was the high peak levels. Limitations in the instrumentation used made it impossible to estimate the number of sudden jolts occurring during each cycle. Only a single peak value was recorded for each work-cycle monitored yet 3 - 4 jolts of a similar level were probably being experienced during each work cycle. Moreover, peak levels above 146 dB (the upper limit in ISO 2631-1978E) were not incorporated into the computed Leq (Rasmussen 1982), which means that the Leq data underestimate the vibration levels to which operators were being subjected. Consequently, crest factors (which are in any case potentially misleading) were not reported.

Also the instrumentation was not capable of identifying the frequencies in which the dominant vibration intensities were occurring. There is very little reported in the literature concerning off-road, whole-body vibration in forestry vehicles. Little is known about the effect of frequent high intensity impacts of the sort that occur as the skidder rides over a stump or boulder or as the blade unexpectedly drives against a stump. It is hard to disagree with Hansson and Wikstrom (1981) that ISO standards for whole-body vibration are difficult to apply to forestry work. The levels observed here need confirmation, but certainly represent cause for concern.

Short-term reductions in some of the adverse consequences of the vibration levels observed may be achievable, but in the long term, a reduction in the amount of vibration to which man and machine are subjected may be needed.

The seat and its associated suspension is only part of the answer to whole-body vibration. Another problem clearly identified by the skidder operators is that they have difficulty in bracing themselves inside the cab against jolts or protecting themselves when bracing cannot be achieved. They reported on the lack of internal grab handles and protective cushioning.

As an aside it is possible that a significant proportion of the daily vibration dose may be absorbed during travel between the logging camp and the cutting area.

**Thermal Conditions**

Many factors contributed to the operators' thermal discomfort. The operator had little control over his thermal environment, partly because the frequency of mounting and dismounting make any cab enclosure system a nuisance. Another was the frequent alternation between highly active work likely to induce sweating and much less active driving. This contrast made it difficult to strike a balance in terms of clothing needs in the winter. Other factors included cold seats and lack of wind protection.

**Noise**

Most of the operators interviewed did not perceive noise as a problem even though noise levels were mostly well above recommended levels for the prevention of hearing loss (OML 1982). Several machines exposed their operators to levels four times the recommended daily dose. Doses over 100 percent were the rule rather than the exception. Thus, despite many studies of this problem (e.g. Reif and Howell 1973; Howell 1974), operators are still being exposed to extreme noise levels. Most operators were reluctant to wear hearing protection because of discomfort or interference with important auditory

signals. However, even when protection is worn, it is likely that it is only partially effective because of deterioration in the protection equipment or improper wearing habits.

**Information needs**

The skidder operator has two important information needs. One is visual information to allow him to pick a route through the bush; the other is information concerning the whereabouts of his feller for both his own and the feller's safety. The former need is hampered primarily by different features of the skidder itself. Viewing to the rear was not only obstructed but also imposed fatiguing postures.

Obtaining information as to the whereabouts of the feller had two associated problems: a restricted visual field from the skidder and through the undergrowth. Lack of contrast between clothing and background adds to the visual detection problems.

A second, and important, indication of the feller's location is the noise of the chainsaw. This is often masked by the noise of the skidder engine when the operator is in his machine. Also when the skidder is in operation, the operator's attention is divided, with much of his concentration focused on the operational needs of the machine and the location of the load away from the feller.

Feller-skidder communication was perceived as important and unsatisfactory by the operators. This is an area inviting further investigation. Possibilities include remote controls for the skidder during winching in, clothing coloration, and alternative auditory communication systems.

**Cab Characteristics**

Internal cab space was, on the whole satisfactory, with the exception of cab height. Mostly the cab roof was too close to the operator's head according to the checklists consulted. This can be contrasted with operators' reports of the cab being too narrow and of frequently striking their heads against the side of the cab when their vehicle hit an obstruction. There was also a lack of internal storage space.

Entrance dimensions were mostly unsatisfactory, both in width and height. This made mounting and dismounting awkward, particularly when steps were not positioned directly below the cab entrance, or the body had to be turned on entering or exiting.

Step height was mostly too high, often considerably so. Step width and depth were more frequently within the recommended range.

External grab handles were present in all cases but all were too far above the ground. Handle lengths varied considerably. Only three internal grab handles were found and all had been fitted at the request of the operator. One of these handles was to help the operator brace himself during driving, and the others were to assist the transition from seat to exit during mounting and dismounting.

**Training**

A final factor worth comment concerns the long experience needed before a skidder operator perceives himself as able to operate effectively. Moreover it is likely that such self-estimates of competence may be far short of possible levels of effectiveness.

Industrial training in general is a much neglected topic and often dismissed as trivial except in the case of highly skilled craftsmen. Standardization and acceleration of the learning experience can benefit most industrial jobs, nevertheless, and the increasing interest in identifying training needs can only result in more effective operations and a safer environment. Operators' estimation of their learning difficulties with different tasks in a work cycle will indicate where training effort can best be concentrated.

## CONCLUSIONS

Most of the negative observations contained in this report stem from two aspects of the skidder systems observed. These are the need to travel across country in the skidder and the need to mount and dismount repeatedly. A decrease in either of these demands might remove many of the concerns identified here because not only would vibration stresses on man and machine be reduced, but also fatigue and slips and falls associated with mounting and dismounting. At the same time the feasibility of an enclosed climate- and noise-controlled cab would be increased.

Such a revised concept depends upon more than human factors; it is a long-term approach. In the short term, many small modifications could be attempted. Some worth considering include:

1. Installation of grab handles inside the cab
2. Installation of improved external grab handles
3. Improved set adjustability
4. Improved thermal insulation for the seat
5. Improved seat back rests
6. Improved step dimensions
7. Protective padding within the cab
8. Increased internal head room.

However, these suggestions deal only with the symptoms not with the root of the problems identified.

To summarize, this study clearly identifies a number of aspects of skidder operations that need more systematic investigation.

First among these is the nature and consequences of the high levels of whole-body vibration to which skidder operators are exposed. Not only should more be known about current exposure levels, their short-term consequences and ways of reducing the immediate impact, but the long-term consequences need to be investigated. Epidemiological research is needed to identify the long-term consequences of exposure to such conditions in terms of spinal, and visceral changes amongst skidder operators past and present. Physiological and performance concomitants of task and environmental stresses need to be investigated in detail.

A second area where improvement should be possible concerns mounting and dismounting in terms of the design of cab entrance, steps and grab rails as well as frequency of mounting and dismounting.

Considerations inside the cab include seating with reference to thermal insulation and back support as well as suspension. Some degree of climate control is also clearly desirable. Finally most operators receive little or no systematically managed training.

Some of the features of skidder operations identified seem fairly simple to improve. Some are less straightforward and require further investigation or confirmation. Some seem likely to strike at the roots of the cut-and-skid operation as a concept.

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POOR

QUALITY

ORIGINAL